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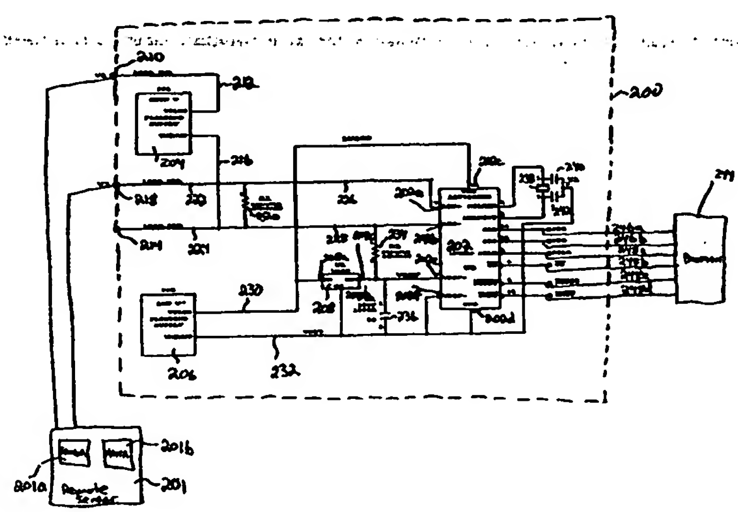

(57) Abstract

An electrical circuit for measuring an analog voltage from an external sensor comprises an a/d converter, first and second single-ended power supplies and a voltage reference. The a/d converter includes a differential input having a relatively high-voltage side and a relatively low-voltage side. The differential input is adapted for receiving a differential signal from an external sensor. The first single-ended power supply provides power and signal ground to the a/d converter. The second single-ended power supply is floating with respect to the first single-ended power supply and provides current to an external sensor, such as a loop powered transmitter. The voltage reference is powered from the first single-ended power supply and provides a common mode voltage bias to the differential input of the a/d converter.

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MEASUREMENT CIRCUIT EMPLOYING DUAL FLOATING POWER SUPPLIES

Technical Field

This invention relates to circuits for measuring signals from sensors. More particularly, the invention is directed to the use of dual floating power supplies in circuits for measuring signals from remotely located sensors, such as loop powered transmitters.

Background of the Invention

Techniques for measuring analog signals from sensors have long been known. Measurement circuits monitor sensor output signals representative of a variety of parameters, such as pressure, temperature, voltage, current, ground fault, flow rate and the like. Some analog sensors provide single-ended output voltage or current signals, while other sensors provide differential output signals. It has long been a challenge to provide measurement circuits that accommodate various types of sensor output signals.

One type of prior analog sensor is a loop powered transmitter. Loop powered transmitters include an input stage and an output stage. The input stage is essentially a sensor circuit. The output stage is essentially a transmitter and typically is powered from a 24-Vdc power supply. A typical transmitter provides a loop current output signal between 4 mA and 20 mA, which is responsive to the magnitude of the parameter being sensed by the sensor circuit. The loop current can be coupled to a sampling resistor, across which the voltage can be sensed. By Ohm's law, the voltage across the sampling resistor is proportionate to the sensor output current. Prior circuits typically employ 50 ohm to 60 ohm sampling resistors, thus providing 0.2 Vdc to 1.2 Vdc output signals. An analog-to-digital (a/d) converter circuit converts the sensed voltage to a digital representation of the magnitude of the parameter being measured. Loop powered transmitters are typically located a few thousand feet or more from the a/d converter circuitry and the 24-Vdc power supply.

Prior measurement circuits generally include a/d converter circuitry or some type of buffering amplifier powered from a bipolar power supply, along with a 24-Vdc loop power supply. The bipolar and loop power supplies are typically common grounded.

Common challenges faced by circuit designers include reducing power supply requirements, avoiding noise and increasing application flexibility. The prior measurement circuits suffer from several deficiencies. One such deficiency is requiring a bipolar power supply. Another deficiency is that with the loop powered transmitter located a few thousand feet or more away and with the power supplies common grounded, the prior circuits couple unwanted noise to the a/d converter circuitry. Additionally, common grounding provides reduced common mode noise rejection and renders it difficult to utilize the prior art circuits to measure differential sensor signals.

Accordingly, an object of the invention is to provide a measurement circuit having simpler power supply requirements.

Another object of the invention is to provide a measurement circuit having reduced noise coupling and increased common mode noise rejection.

A further object of the invention is to provide a measurement circuit that can accommodate both single-ended and differential sensor signals.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

Summary of the Invention

The invention attains the foregoing objects by providing a measurement circuit that includes an electrical element having a differential input; first and second power supplies; and a voltage reference. According to one embodiment, the electrical element includes a differential amplifier. According to another embodiment, the electrical element includes an a/d converter. The differential analog input has a relatively high-voltage side and a relatively low-voltage side and is adapted for receiving an output

signal from an external sensor. The first power supply provides power and signal ground to the electrical element. The second power supply provides current to the external sensor. The voltage reference is powered from the first power supply and provides a common mode bias to the differential input.

According to a further embodiment, the first power supply is a single-ended supply and the a/d converter is adapted for being powered from the single-ended supply. Additionally, the voltage reference can also provide a selected reference voltage to the a/d converter. In another embodiment, the external sensor is a remotely located loop powered transmitter. According to a noise decoupling feature, the first and second power supplies are not common grounded (i.e. the first and second power supplies are floating with respect to each other). By floating the power supplies, the return from the loop powered sensor can be decoupled from the signal ground of the a/d converter, thereby diminishing the coupling of noise from the loop powered transmitter. Additionally, decoupling the grounds enables a circuit according to the invention to measure both single-ended and differential sensor output signals and to provide improved common mode noise rejection.

According to a further embodiment, a measurement circuit according to the invention includes only one single-ended power supply for providing power and signal grant to the a/d converter.

Thus, the invention provides an improved circuit for measuring an analog signal from a sensor, such as a loop powered transmitter. A measurement circuit, according to the invention, reduces the number of power supplies, from the prior requirements of a single-ended and a bipolar power supply to two single-ended power supplies. Additionally, the invention reduces the introduction of electrical noise, by floating the two power supplies with respect to each other and by decoupling the loop transmitter return from the signal ground.

Brief Description of the Drawings

The subject matter regarded as the present invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and methods of practice, together with further objects and advantages, may be understood by reference to the following illustrative description taken in conjunction with the accompanying drawings, in which like numerals refer to like elements, and in which

FIGURE 1 is a schematic diagram of a typical prior art circuit for measuring an electrical signal from a remotely located sensor; and

FIGURE 2 is a schematic diagram of a circuit according to the invention for measuring an electrical signal from a remotely located analog sensor.

Description of Illustrated Embodiment

An electrical measurement circuit according to the invention employs dual floating power supplies, i.e., the circuit employs two electrical power supplies that do not have a common electrical ground connection. The measuring circuit of the invention requires only two single-ended power supplies and yet provides at least the same performance as prior circuits that require the more complex and more costly combination of both a single-ended supply and a bipolar supply. A further feature of the measuring circuit of the invention is that it is less susceptible to the introduction of electrical noise, and has higher rejection of common-mode noise, compared to prior circuits having a bipolar power supply.

FIGURE 1 is a schematic diagram of a typical prior art circuit 100 for measuring a signal from a remotely located sensor 102. The illustrated sensor 102 is a loop powered transmitter having a sensor portion 102a and a transmitter portion 102b. The measurement circuit 100 includes a 24-Vdc power supply 104, a bipolar ± 5-Vdc power supply 106 and an a/d converter 108. The power supply 104 supplies voltage to the loop powered transmitter 102 by way of the connection 110 and the interface terminal 112. The sensor portion 102a of the loop powered transmitter 102 monitors a selected

parameter such as temperature, pressure, flow rate, ground fault current or the like. The transmitter portion 102b, in response, provides an output signal, typically a dc current between 4 mA and 20 mA, which is responsive to the magnitude of the sensed parameter. The transmitter portion 102b electrically couples the output current signal to measurement circuit 100 by way of an interface terminal 118. The output current signal is then passed through the sampling resistor 120 by way of lines 122 and 124. The voltage developed across the sampling resistor 120 due to the transmitter output current is coupled to the differential inputs 108a and 108b of the a/d converter 108 by way of the lines 126 and 128.

The bipolar supply 106 provides a +5-Vdc supply voltage to the terminal 106c of the a/d converter 108, by way of the line 130. The supply 106 also provides a –5-Vdc supply voltage to the terminal 108d of a/d converter 108, by way of the line 132. The supply 106 further provides signal ground to the terminal 108e of the a/d converter 108, by way of the line 134. The supply 106 also powers the voltage reference 136.

The voltage reference 136 provides a 2.5-Vdc reference voltage across the reference terminals 108f and 108g of the a/d converter 108. The capacitor 138 filters the output voltage from the reference 136. The a/d converter 108 employs the reference voltage 136 across the terminals 108f and 108g in a known manner to perform an a/d conversion of the voltage presented across the terminals 108a and 108b. The crystal 140, along with the capacitors 142 and 144, provide a clock signal across terminals 108h and 108i of the a/d converter 108. The a/d converter 108 employs this clock signal in a known manner to aid in the a/d conversion of the voltage signal presented across the input terminals 108a and 108b. Operation of the a/d converter 108 can be controlled by an external processor 150 in a known fashion by way of the optically isolated control signals 148a-148d. Additionally, by way of the optically isolated serial ports 146a and 146b, the a/d converter 108 provides the external processor 150 with a digital representation of the analog signal applied across the input terminals 108a and 108b.

The measurement circuit 100 of FIGURE 1 illustrates the above mentioned drawbacks of prior approaches to measuring signals from remotely located sensors, such as loop powered transmitters. By way of example, assuming that the sampling resistor 120 is 60 ohms, the voltage developed across the resistor 120 due to the 4 mA – 20 mA output current from the transmitter 102b is between .24-Vdc and 1.2-Vdc. To precisely measure voltages so close to ground, the a/d converter 108 employs the bipolar voltage supply 106. Additionally, according to the configuration of the circuit 100, the return from the loop powered transmitter 102b connects to the signal ground from the power supply 104 at point 152. With the loop powered transmitter 102 a few thousand feet or more from the measurement circuit 100, connecting signal ground to the loop return increases the likelihood of coupling noise into circuit 100. Tying the loop return to signal ground also reduces common mode noise rejection typically associated with a differential input, such as that provided by inputs 108a and 108b.

FIGURE 2 depicts a measurement circuit 200 according to an illustrative embodiment of the invention. According to the illustrated embodiment, circuit 200 measures an output signal from a loop powered transmitter 201 However, according to other embodiments, the circuit 200 can be employed to measure signals from other types of sensors, such as thermocouples. The illustrated measurement circuit 200 includes an a/d converter 202, a 24-Vdc power supply 204, a 5-Vdc power supply 206 and a 2.5-Vdc voltage reference 208. The a/d converter 202 can be a AD7705BRU, which uses a single-ended 5-Vdc supply voltage and is available from Analog Devices, Inc.

The power supply 204 provides current to the remotely located loop powered transmitter 201 by way of a terminal 210 and a line 212. The power supply 204 also provides a return signal to a terminal 214 by way of a line 216. As discussed above, the loop powered transmitter includes a sensor portion 201a and a transmitter portion 201b The transmitter portion 201a provides a current signal, typically between 4 mA and 20 mA, which is representative of the magnitude of a parameter which the sensor portion senses. The output current signal from the transmitter 201b couples into the measurement circuit 200 by way of an interface terminal 218. Lines 222 and 224 pass the signal to a sampling resistor 220. The resultant voltage developed across sampling

resistor 220 is coupled to the differential inputs 202a and 202b of the a/d converter 202 by way of lines 226 and 228. In this way, the input terminal 202a is maintained at a relatively higher voltage with respect to the input terminal 202b.

The power supply 206 provides a dc voltage, illustratively 5-Vdc, to a supply terminal 202c of the a/d converter 202 and to a reference input terminal 208a of the voltage reference 208, by way of line 230. The power supply 206 also provides signal ground to a ground terminal 202d of the a/d converter 202 and to a ground terminal 208b of the voltage reference 208. The voltage reference 208 couples a dc reference voltage, illustratively 2.5-Vdc, across reference input terminals 202e and 202f of the a/d converter 202, from a reference output terminal 208c. The voltage reference 208 also couples the dc reference voltage through a coupling resistor 234 to one differential input 202b of the a/d converter 202. With coupling resistor 234 typically on the order of 10 kohms, the voltage reference 208 effectively provides a common mode bias, of 2.5-Vdc in the illustrated example, to the differential inputs 202a and 202b.

As in the case of the FIGURE 1 circuit 100, a capacitor 236, in the FIGURE 2 measurement circuit, filters the output voltage from reference 208. Further, a crystal 238, along with capacitors 240 and 242, provides a clock signal to the a/d converter 202, and optically isolated signals 248a-248d enable the a/d converter 202 to be controlled from a digital controller 244 in a known fashion. Additionally, the optically isolated serial ports 246a and 246b provide a digital representation of the analog voltage across the terminals 202a and 202b to the processor 244.

In operation, the voltage developed across the sensing resistor 220, as a result of the parameter-responsive output current from the loop powered transmitter, couples across the differential input terminals 202a and 202b of the a/d converter 202. As discussed above, in the prior art circuit 100, this results in a voltage typically ranging between approximately 0.24 Vdc - 1.2 Vdc, being coupled to the a/d converter 202, and necessitates the use of the bipolar voltage supply 104. However, with the voltage reference 208 providing a dc common mode bias voltage in accord with the invention, the voltage across the differential inputs 202a and 202b instead has a materially higher

level, typically ranging between approximately 2.74 Vdc –3.7 Vdc, which enables the use of single-ended dc power supply 206. The a/d converter 202, under the control of the optically isolated signals 248a-248d, converts the analog voltage across the differential input terminals 202a and 202b to a digital representation.

The foregoing measurement circuit 200 provides several important advantages over prior art circuits such as the FIGURE 1 circuit 100. The common mode bias applied to the differential inputs 202a and 202b eliminates the need for a bipolar power supply. Another advantage is that uncoupling the signal ground from the loop return reduces the opportunity for noise to couple from the loop powered transmitter to the signal ground. A further advantage of floating the supply 204 with respect to the supply 206 is that the measurement circuit 200 provides a true differential input across the sampling resistor 220, thus providing improved common mode noise rejection.

Also, the measurement circuit 200 of the invention requires no further electrical supplies to attain the foregoing advantage. Instead, it utilizes the same single-ended power supply to power voltage reference 208 as it uses to power the a/d converter 202. The reference 208 provides both a reference voltage to the a/d converter 202 and also provides a common mode bias voltage to the differential inputs 202a and 202b. In addition, the common mode bias of the invention draws minimal current from the reference supply 208.

Although the power supply 204 is shown as part of circuit 200, in alternate embodiments it can be removed from circuit 200 and located proximate to the remote sensor 201. To that end, the circuit 200 provides a terminal 214 for connecting the return from the remotely located power supply 204 back to the circuit 200.

Additionally, the circuit 200 depicts the loop return current being sampled across the resistor 220, with the voltage developed across the resistor 220 being measured by the a/d converter 202. However, according to the invention, the combination of the resistor 220 and the a/d converter 202 is only illustrative and can be replaced with any electrical/electronic processing circuit adapted for processing a differential input

voltage, wherein the processing circuit is powered by a single single-ended power supply, and the differential input is common mode biased.

It will thus be seen that the invention efficiently attains the objects set forth above, including providing a circuit for measuring signals from remotely located sensors, such as loop powered transmitters and thermocouples. Since certain changes may be made in the above constructions and the described methods without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings be interpreted as illustrative and not in a limiting sense.

Having described the invention, what is claimed as new and protected by Letters Patent is:

Claims

1. An electrical circuit for measuring an electrical analog signal comprising

an electrical element including a differential analog signal input having a relatively high-voltage side and a relatively low-voltage side, said differential analog signal input being adapted for receiving an analog signal from an external sensor,

a first power supply for providing power and signal ground to said electrical element,

a voltage reference adapted for providing a common mode voltage bias to said differential analog signal input, and

a second power supply referenced to said relatively low-voltage side of said differential input and adapted for supplying current to said external sensor.

2. An electrical circuit for measuring an electrical analog signal according to claim 1 wherein said electrical element includes an a/d converter.

3. An electrical circuit for measuring an electrical analog signal according to claim 1, wherein said external sensor includes a loop powered transmitter.

4. An electrical circuit for measuring an electrical analog signal according to claim 2, wherein said voltage reference is adapted for supplying a selected reference voltage to said a/d converter.

5. An electrical circuit for measuring an electrical analog signal according to claim 1, wherein said voltage reference is powered from said first power supply.

6. An electrical circuit for measuring an electrical analog signal according to claim 1, wherein said second power supply is floating with respect to said first power supply.

7. An electrical circuit for measuring an electrical analog signal according to claim 2, wherein said a/d converter is adapted for being powered by a single-ended power supply.

8. An electrical circuit for measuring an electrical analog signal according to claim 7, wherein said first power supply provides a single output voltage to said a/d converter.

9. An electrical circuit for measuring an electrical analog signal according to claim 2 and free of any additional power supply for providing power and signal ground to said a/d converter other than said first power supply.

10. An electrical circuit for measuring an electrical analog signal according to claim 6, wherein said second power supply provides a single output voltage to said sensor.

11. An electrical circuit for measuring an electrical analog signal comprising

a first single-ended power supply referenced to a signal ground,

an analog-to-digital converter powered from said first single-ended power supply, wherein said analog-to-digital converter includes a reference voltage input and a differential analog signal input having a relatively high voltage side and a relatively low voltage side, said differential analog signal input being adapted for receiving an analog output signal from an external sensor,

a reference voltage circuit powered from said first single-ended power supply, and providing said reference voltage between said reference voltage input and said signal ground, and providing a common mode voltage bias to said differential analog signal input, and

a second single-ended power supply, referenced to said relatively low voltage side of said differential analog signal input and floating with respect to said signal ground, said second single-ended power supply powering said external sensor circuit.

12. An electrical circuit for measuring an electrical analog signal comprising

an a/d converter having differential input means for coupling to an analog output signal from an external sensor and being adapted for being powered from a single single-ended supply voltage,

first power supply means for providing a single-ended supply voltage, along with signal ground to said a/d converter means,

voltage reference means for providing a common mode bias voltage to said differential input means, and

second power supply means for supplying current to said external sensor, wherein said second power supply means is substantially floating with respect to said first power supply means.

13. An electrical circuit for measuring an electrical output signal from a loop powered transmitter, comprising,

an a/d converter including a differential analog signal input, having a relatively high-voltage side and a relatively low-voltage side, said differential analog signal input being adapted for receiving an analog output signal from a loop powered transmitter,

a first single-ended power supply for providing power and signal ground to said a/d converter,

a voltage reference, powered from said first power supply and adapted for providing a common mode voltage bias to said differential analog signal input, and

a second single-ended power supply, floating with respect to said first power supply, referenced to said relatively low-voltage side of said differential input, and adapted for supplying current to said loop powered transmitter.

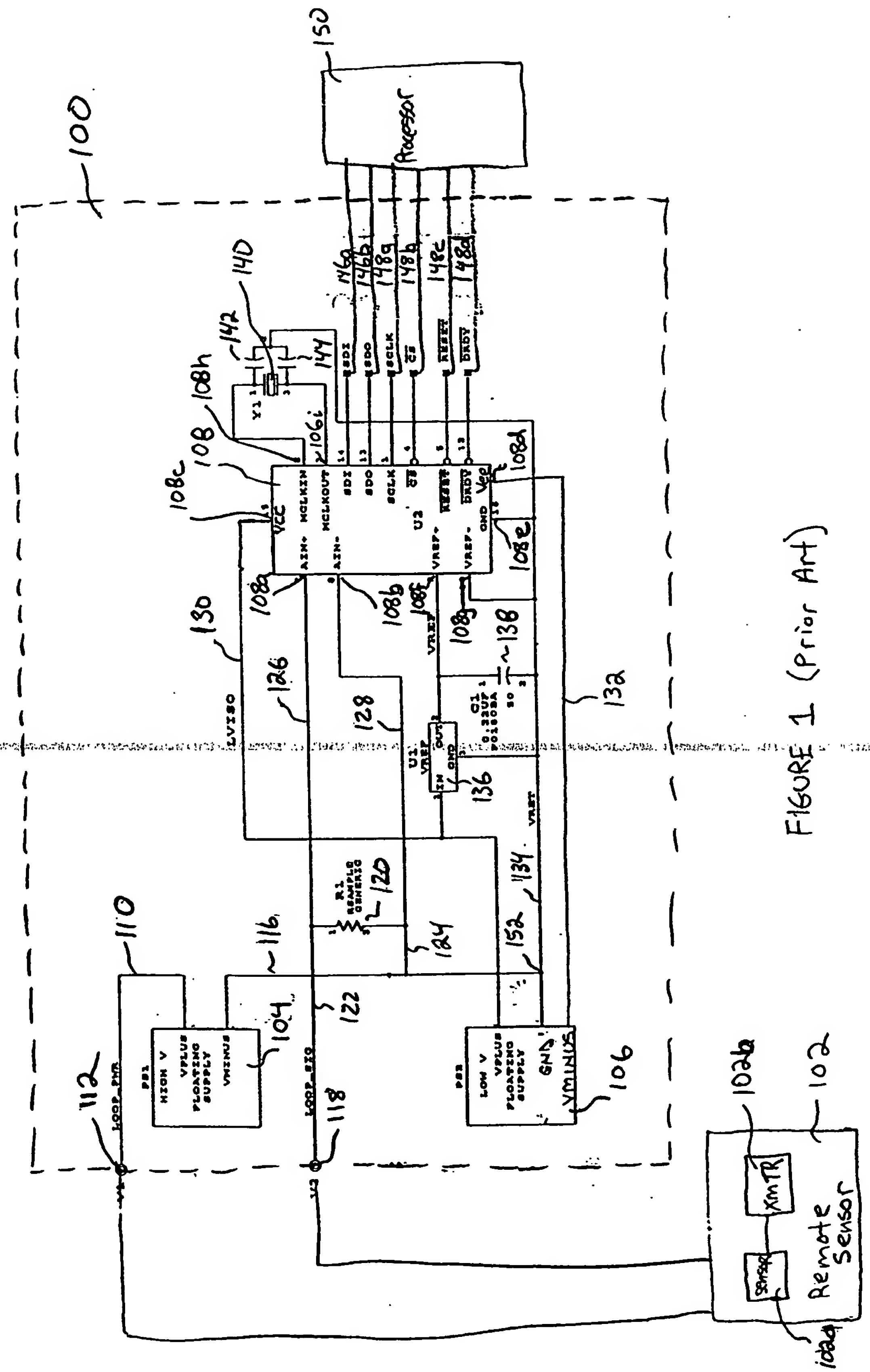
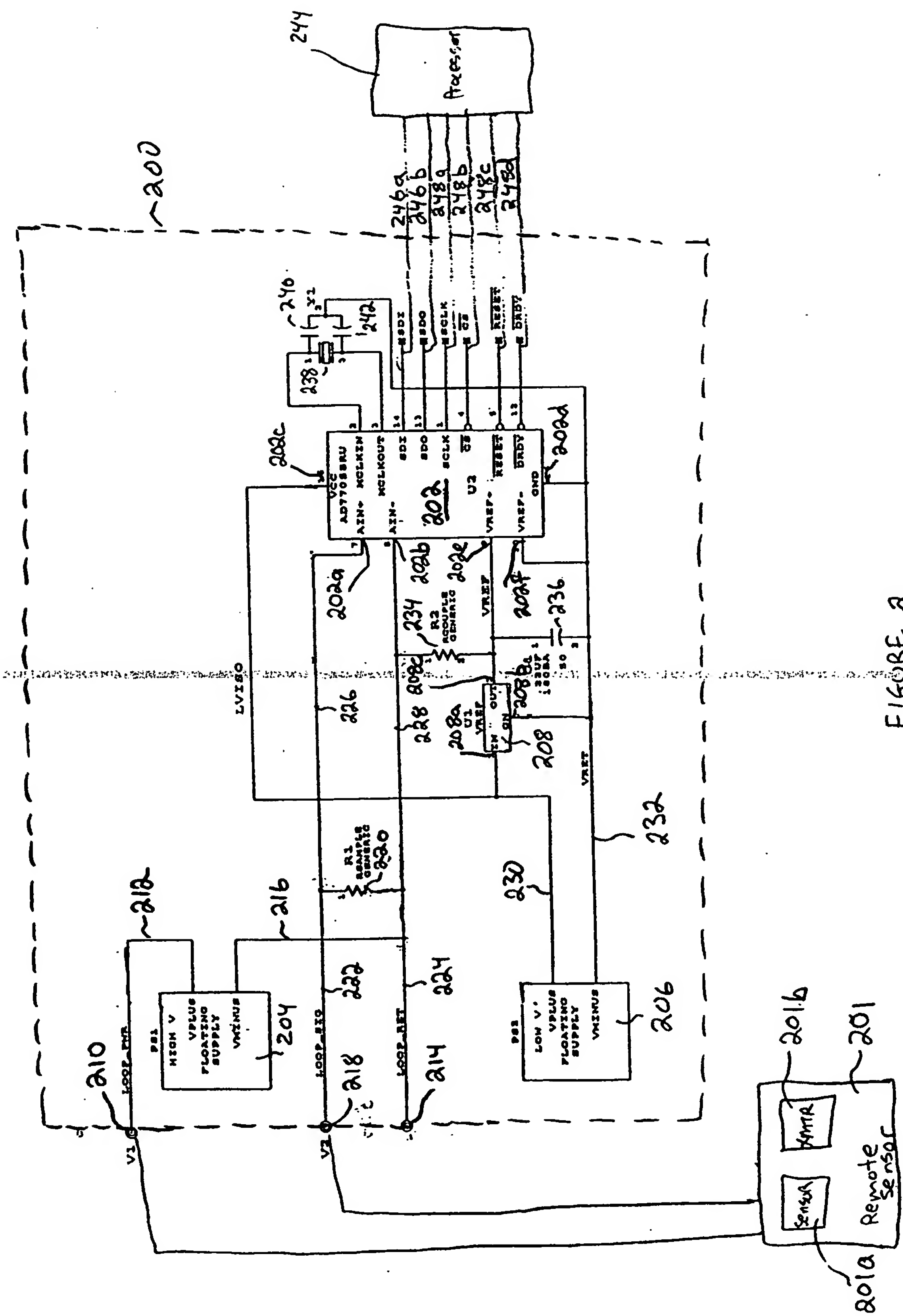


FIGURE 1 (Prior Art)



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201
244

FIGURE 2